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SELECTIVE ATTENTION SKILLS OF EXPERIENCED SONAR OPERATORS¹

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Summary.—This study investigated the influence of sonar training and experience on the selective attention of experienced and inexperienced operators. The Stroop task was selected as a measure of general selective attention, similar in certain task requirements (attentional allocation) to sonar operation. Across two samples ($n_s = 32$ and 36) and four repeated test sessions groups did not differ significantly in speed or accuracy of Stroop performance. The data suggest that experienced operators do not seem to have developed extraordinary attentional skills and that any attentional skills developed through sonar experience do not generalize to other tasks such as the Stroop.

Several studies recently have shown that older, more experienced sonar operators perform somewhat differently than younger, less experienced operators and comparison subjects on a variety of cognitive and personality measures. For example, Kobus, Beeler, and Stashower (1987) and Kobus and Stashower (1988) found that experienced operators have a significantly different distribution of brain electrical activity recorded during a selective attention task than nonexperienced operators and suggested that these results may represent differences between automatic and controlled cognitive processes. Merrill (1990) suggested that experienced operators display significantly different brain activity and that activity may be associated with practiced attentional and evaluative processes. Further, Kobus, Lewandowski, and Flood (1987) administered a battery of cognitive and personality tests to experienced operators and trainees. They found that experienced operators had better perceptual-organizational abilities, gave greater attention to visual details, and reported less anxiety (state) than inexperienced subjects.

In a similar study that controlled for the confound of age and experience, Lewandowski, Kobus, Flood, and Hoyer (1988) reported that experienced operators outperformed comparison subjects on a sonar simulation task regardless of age. They also found these operators to display a more "reflec-

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tive" cognitive style, spending more time on visual search tasks and performing with greater accuracy. Over-all, these studies cautiously suggest that experienced operators perform better than average operators and also better than less experienced peers on tasks requiring visual attention, perception, and organization, particularly when the visual information is embedded in a distracting background.

These findings raise a question as to whether sonar experience might enhance operators' visual perceptual-cognitive abilities. Research has shown that highly practiced and automatized functions can enhance cognitive abilities related to a person's domain of expertise (Bedard & Chi, 1992). Studies on "expert cognition" (Glaser, 1986) have investigated such diverse functions as memory of chess players, reading and comprehension, medical diagnosis, and other mental activities which require learning and experience. For the sonar operator the expert domain seems to involve the process of selectively attending to visual or auditory signals embedded in a noise background. If this is so, the research question then becomes, does sonar experience enhance operators' general selective attention?

It has been demonstrated that sonar operators are better performers on sonar-like tasks than nonoperators (Lewandowski, *et al.*, 1988); however, we do not know if this superiority is due to enhanced selective attention or merely to the amount of practice. There is no unbiased way to compare performance between experienced and inexperienced operators on tasks already familiar to the sonar operator. A fair comparison would employ a novel task that assesses selective attention, yet is not biased in favor of the sonar operator. Operators' superiority on a more "generic" test of selective attention would argue for the development of certain information-processing strengths as a result of their job experience.

The Stroop Color-Word Test (Stroop, 1935) has been used for just such a purpose (Dyer, 1973). This test requires subjects to name the incongruent color of ink with which a word is printed and to ignore semantic content. Color-words in congruent ink color, e.g., the word RED printed in red ink, produce faster color-naming responses than color words in incongruent ink, e.g., the word RED printed in green ink. This slowing of response has been labeled the "Stroop interference effect." The effect is predicated on response competition whereby word reading must be suppressed to be successful at color naming. Certain elements of this task are similar to sonar operation in that competing and distracting signals must be filtered from visual information containing target stimuli. In this sense, both tasks require selective attending to essential versus nonessential visual information, and both need to be performed in a fast and automatic fashion. Based on these similarities, the Stroop was considered to reflect some of the same abilities required in sonar operation and thus could be used to assess selective attention. Im-

portantly, the Stroop-task content was removed enough from sonar operation to make it novel regardless of the subjects' previous experience.

The purpose of this study was to examine whether selective attention, as assessed by Stroop-test performance, is differentially influenced by sonar training and experience. The rationale was that significant sonar experience would create a specialized domain of expertise in the operator along the line of enhanced visual attention and that this expertise would generalize to other selective-attention tasks, i.e., the Stroop. Therefore, the present study compared groups of experienced and inexperienced operators on the Stroop test. Because attention can be easily affected by extraneous variables, thereby lowering test reliability, subjects were administered the task twice, and retest reliability was computed. It was expected that all subjects would perform slightly better in the second session due to practice (Reisberg, Baron, & Kemler, 1980). It was also hypothesized that experienced operators would perform the Stroop test faster and with fewer errors than the inexperienced subjects.

The utility of an instrument that assesses selective attention similar to that required in sonar should not be underestimated. Recently, Kobus and Lewandowski (1992) found that most of the 538 sonar operators surveyed listed "attention ability" as the factor most critical to sonar operation. It may be that selective attending, the ability to perform well despite information interference, is a common characteristic among successful sonar operators. A brief test of this characteristic could be of assistance in assessing the performance of prospective and experienced sonarmen.

EXPERIMENT 1

Method

Subjects.—Thirty-two U.S. Navy men were recruited from the Anti-Submarine Warfare School (ASW) in San Diego, California as volunteer subjects. Two groups were formed based on experience. The experienced group consisted of 16 subjects who had two or more years of sonar operational experience ($M = 3.2$); they ranged in age from 20 to 23 years ($M = 21.8$). The inexperienced group consisted of 16 subjects with no sonar operational experience or training although they had been selected for training; they ranged in age from 19 to 24 years ($M = 20.8$). Each subject's hearing and visual acuity were self-reported as within normal limits.

Materials.—A color-only version of the Stroop test similar to one used by Comalli, Wapner, and Werner (1962) was administered to each subject. A sheet of white 8½-in. by 11-in. paper was printed with 10 rows of 10 color-words each. Three words denoting color were used, RED, BLUE, and GREEN. All words were printed with an incongruent color (their color did not match their lexical representation). The 100 color-words were randomly presented in 10 rows of 10 words each.

Procedure.—Subjects completed the Stroop test in a quiet, empty classroom. The test was administered on two occasions with two weeks separating the sessions. Subjects were instructed to verbalize the color of ink in which each word was printed as quickly as possible. They were told not to correct themselves if they made a mistake but to continue to the next word. Subjects were told to begin identifying the colors at the top left-hand corner and to proceed from left to right. To verify subjects' comprehension of the task, each subject was given 10 practice words to read. Next, the test sheet was placed in front of the subject and a tape-recorder was used to record verbal responses. An experimenter timed the length of each session with a stopwatch. The taped responses were scored for number of errors.

Results

Mean Stroop-test speed and errors for each group and both sessions are presented in Table 1. The length of time it took the subjects to complete each session was analyzed by means of a 2×2 (group \times session) multivariate analysis of variance with session as a within-subject factor. No effect of group was found. A main effect of session was statistically significant ($F_{1,30} = 9.39$, $p < .05$). As predicted, subjects took significantly longer to complete the task in the first session ($M = 89.03$ sec.) than in the second session ($M = 78.50$ sec.). The interaction of group by session approached statistical significance ($F_{1,30} = 3.52$, $p = .07$). Exploration of this trend indicated that the inexperienced group took longer to complete the task in the first session whereas performance was similar for both groups in the second one.

TABLE 1
MEAN STROOP COLOR-WORD TEST SPEED AND ERROR SCORES
FOR EACH GROUP AND SESSION ($n = 16$)

Group	Session 1				Session 2			
	Speed		Errors		Speed		Errors	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Experienced	85.69	22.4	2.81	3.4	78.75	15.6	2.19	1.9
Inexperienced	92.38	13.2	5.25	3.9	78.25	13.1	1.81	1.8

A 2×2 (group \times session) multivariate analysis of variance was performed on the error rates with session as a within-subject factor. A main effect of session was found ($F_{1,30} = 30.19$, $p < .05$). Subjects made more errors in the first session ($M = 4.0$) than in the second one ($M = 2.0$). There was a significant interaction of group by session ($F_{1,30} = 4.50$, $p < .05$). These results paralleled the results of the speed-of-response measure. The inexperienced subjects made more errors in the first session; however, in the second one performance was similar for both groups.

Test-retest Pearson product-moment correlations were significant for speed ($r_{12} = .79$, $p < .001$) but not for errors ($r_{12} = .16$, $p = .19$, two-tailed)

which indicates that speed but not error rate was reliable from session to session. Pearson correlations were computed between speed and errors for Session 1 ($r_{12} = .15$, $p = .20$, two-tailed) and Session 2 ($r_{12} = .25$, $p = .09$). These low correlations suggested little trade-off between speed and error rate but, rather, showed a slight relation between making errors and slowing performance.

Discussion

The results of the study are mixed. Inexperienced operators appeared to perform more slowly and with more errors in the first session than experienced operators; however, these differences diminished in the second session. The data from this experiment have not answered the question of whether operators' experience influences selective attention. Had we run just one session we may have concluded prematurely that experienced operators possessed superior selective attention. After two sessions the picture appears to change. The question becomes whether there are reliable group differences or whether initial effects were due to other variables, i.e., anxiety, cognitive differences, too few sessions.

EXPERIMENT 2

Based upon the mixed findings of the first experiment, it seemed appropriate to repeat the study with several modifications. The most important change was to increase the number of test sessions to clarify the reliability of group differences between operators with and without experience. Harbeson, Krause, Kennedy, and Bittner (1982) suggested that Stroop performance does not asymptote until approximately four sessions, and so the second experiment employed four sessions. A stable finding in support of the hypothesis would show consistent speed and accuracy and advantages for experienced operators across sessions.

We also reasoned that the initial performance of the experienced group may have been due to variables such as cognitive abilities or lower state anxiety (Lewandowski, *et al.*, 1988). Therefore, in the second experiment additional measures of short-term memory and state anxiety were included. Any group differences on these measures could be partialled out of the Stroop analysis, yielding a more pure comparison on the measure of selective attention.

Method

Subjects.—Thirty-six men from the Anti-Submarine Warfare School (ASW) and the Naval Health Research Center in San Diego, California were recruited as volunteer subjects. Subjects were selected with and without sonar experience. The inexperienced group consisted of 18 subjects who had no operational sonar, radar, air-traffic control, or related experience or training. Their ages ranged from 21 to 41 years ($M = 29.0$, $SD = 6.6$). The ex-

perienced group consisted of 18 subjects who had two or more years of operational sonar experience ($M = 6.3$, $SD = 2.2$). Their ages ranged from 24 to 35 years ($M = 28.2$, $SD = 3.2$). All subjects' hearing and visual acuity were within normal limits (or corrected to normal) as indicated by self-report.

Materials.—Exp. 2 used the same Stroop test used in Exp. 1. The Digit Span subtest of the Wechsler Adult Intelligence Scale (WAIS—R; Wechsler, 1981) was used as a check of short-term memory, a cognitive variable that may have favored one group. The State-Trait Anxiety Inventory (Spielberger, 1983) was administered to examine whether inexperienced subjects were more test-anxious than experienced operators.

Procedure.—The procedure was similar to that in Exp. 1, with the exception of four test sessions at 2-wk. intervals and two additional measures, the Digit Span and the State-Trait Anxiety Inventory. The procedure was identical for each session except that the trait portion of the inventory was only administered in the first session. The order of testing for each session was State-Trait Anxiety Inventory, Stroop test, and Digit Span.

Results

To estimate the retest reliability of the Stroop test the speed and error measures were subjected to Pearson correlations between sessions (Table 2). As can be seen in Table 2, speed but not error rate was reliable over sessions. The correlation between speed and error rate was computed over sessions to estimate the association between the two measures and no significant correlations were found. The low error-rate correlations may be attributed to the small number of errors and the truncated range which limited the variance among subjects.

TABLE 2
STROOP COLOR-WORD TEST: PEARSON CORRELATIONS OVER SESSIONS

Sessions	Speed		Errors	
	<i>r</i>	<i>p</i> *	<i>r</i>	<i>p</i> *
1 & 2	.80	< .01	.56	< .01
2 & 3	.71	< .01	.16	.36
3 & 4	.85	< .01	.25	.15

*Two-tailed.

Stroop speed.—Table 3 shows group means for Stroop speed (in seconds). Stroop completion time did not differ significantly between groups ($F_{1,31} = .08$, $p < .78$), so there was no support for the hypothesis of enhanced attention abilities for experienced subjects. There was a significant effect of session ($F_{3,102} = 98.52$, $p < .01$). Mean times of the entire sample decreased from Session 1 to Session 4.

Stroop errors.—Mean group errors per session are listed in Table 4. The

TABLE 3
STROOP COLOR-WORD TEST: SPEED SCORES (IN SECONDS) FOR BOTH GROUPS (n s = 18)

Session	Inexperienced Group		Experienced Group	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
1	93.8	12.3	94.3	14.0
2	83.1	13.6	82.6	09.9
3	76.6	11.2	75.5	11.9
4	73.8	09.7	70.9	10.9

groups did not differ significantly in number of Stroop errors ($F_{1,14} = 1.55$, $p < .22$), again refuting the notion of enhancement of attention. There was, however, a significant effect of session ($F_{3,102} = 6.76$, $p < .01$). The sample means for Sessions 1 through 4 were 3.9 ($SD = 4.2$), 2.1 ($SD = 3.1$), 1.4 ($SD = 1.5$), and 1.8 ($SD = 2.8$), respectively.

TABLE 4
STROOP COLOR-WORD TEST: ERROR SCORES FOR EACH GROUP (n s = 18)

Session	Inexperienced Group		Experienced Group	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
1	3.1	3.5	4.7	4.8
2	1.8	2.6	2.5	3.5
3	1.2	1.5	1.6	1.5
4	1.4	2.2	2.2	3.3

State-Trait anxiety.—Mean scores on the State-Trait Anxiety Inventory for both groups are presented in Table 5. No significant difference was found between the groups for the State or Trait Anxiety measures. A significant effect of session was found for the State measure ($F_{3,102} = 4.42$, $p < .01$), suggesting that state anxiety decreased as test sessions (familiarity) increased. There was no interaction of group by session.

TABLE 5
MEANS AND STANDARD DEVIATIONS FOR STATE-TRAIT ANXIETY
INVENTORY FOR BOTH GROUPS (n s = 18)

Scale	Session	Inexperienced Group		Experienced Group	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Trait Anxiety	1	34.2	7.0	32.7	6.0
State Anxiety	1	34.1	8.2	36.6	7.2
	2	32.9	0.4	31.7	7.1
	3	30.9	8.8	30.5	8.8
	4	32.4	10.3	31.4	6.8

WAIS—R Digit Span.—Mean scores for the Digits Forward and Backward tasks are presented in Table 6. No significant group effects or inter-

actions were observed. A significant effect of session was found for Digits Forward ($F_{1,102} = 4.80$, $p < .01$) and Digits Backward ($F_{1,102} = 9.50$, $p < .01$). Both groups appeared to benefit from practice.

TABLE 6
WAIS—R DIGIT SPAN SCORES FOR BOTH GROUPS ($N = 18$)

Task	Session	Inexperienced Group		Experienced Group	
		M	SD	M	SD
Digits Forward	1	09.2	2.3	09.2	2.1
	2	10.1	1.8	09.6	2.4
	3	10.3	1.7	09.7	2.0
	4	09.9	1.8	10.6	1.9
Digits Backward	1	07.4	1.6	06.7	2.0
	2	08.2	2.2	07.3	2.4
	3	08.6	2.0	08.1	2.5
	4	08.9	2.2	08.1	2.2

GENERAL DISCUSSION

The results of these experiments indicate that experienced operators do not show superior selective attention that generalizes to other tasks such as the Stroop. Their superior ability to attend to selective stimuli may be limited to the specific tasks that they perform as part of their duties and thus may be the result of practice. Kobus, Beeler, and Stashower (1987) have suggested that experienced operators score significantly higher on tests of visual perception. This ability, however, does not seem to be related to performance on the Stroop test wherein the verbalization of the distracting stimulus (words) must be suppressed in favor of the target stimulus (colors).

Although the Stroop test may be an index of selective attention, it does not distinguish experienced operators from inexperienced subjects. Our results show a distribution of Stroop speed and accuracy that places both subject groups within the same population. In fact, Exp. 2 showed the groups to be very similar on all variables, including the memory and anxiety measures. It appeared that we had a fair comparison of two matched samples with the exception of sonar experience and that experience did not produce expertise on the Stroop task.

Stroop speed but not accuracy was a reliable measure over sessions. Our test-retest reliability coefficients for speed are comparable to those reported in other studies (Harbeson, *et al.*, 1982; Jensen, 1965; Jensen & Rohwer, 1966). Therefore, if a genuine difference had existed between groups, it would have been documented by the speed measure. The use of errors to test the hypothesis is questionable as retest reliability estimates were rather low and unstable. Regarding errors, no other report of the test-retest reliability was found in the literature. Accuracy from session to session may not be significantly correlated because the number of errors that most of the sub-

jects committed was small. The small range of errors also may have contributed to the nonsignificant correlations between speed and errors within sessions. Low error rates might suggest that the Stroop test was not difficult enough to put a strain on attentional resources, and therefore it may not be a sensitive test for detecting the specialized attentional skills of sonarmen.

Based on our Stroop data collected for different samples across multiple sessions, it appears essential that investigators employ repeated testings and sample replication; otherwise they run the risk of making Type I errors in interpretation. At the same time, it is important that a valid hypothesis is not erroneously rejected. In this study a 10-sec. difference between groups would have had an 81% chance of being detected. The results, however, showed not only was the difference less than 10 sec. but the direction of difference on the error measure was opposite from the hypothesized direction.

It appears that the Stroop task is not a valuable tool for assessing the performance of personnel who would be good sonar operators. In this study there were no differences on the Stroop between experienced and inexperienced operators, with similar amounts of variance within each group. It may be that the Stroop task is sufficiently different from a sonar task and novel for all subjects, thereby yielding equivalent performances. Another difference between the Stroop task and sonar is the duration of each and the types of attention required. Sonar operation requires long watches (4 to 6 hours) of sustained attention to a variety of auditory and visual stimuli embedded in noise. The Stroop task requires approximately 90 sec. of focused attention on static visual stimuli with two features (color and color names). The requirements of the Stroop task may be too far removed from those in sonar to expect an advantage for experienced (expert) sonarmen.

Research in the area of "expert cognition" (Glaser, 1986) has suggested that persons who are highly experienced or practiced in a particular skill, e.g., chess or radiology, are able to maintain high levels of performance of the skill over age. Therefore, even older experts, who may show declines in certain cognitive or motor tasks, do not evidence a decline in performance of the specialized skill [see Bedard & Chi (1992) for a review]. Such findings suggest that the development of an expertise which is resilient to aging effects and other forms of degradation is relegated to a narrow content or skill domain. It may be that such an expertise is confined to the sonar task itself and does not generalize to other tangential tasks such as the Stroop. To capture the expertise of sonarmen, investigators may need to develop simulations or a test battery that contains the essential ingredients of sonar, e.g., vigilance, sustained attention, signal sensitivity.

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